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Using Environmental News to Help Teach Mathematics

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Do you teach at a school where there is an opportunity to develop new courses in environmental mathematics? Is there time available in your courses to develop major projects involving building models of environmental problems? Those who can answer "yes" to such questions are fortunate indeed. But even if your answers are "no," it is possible for those of us with an interest in the environment to use this topic in a wide variety of courses in such a way as to help teach math, develop quantitative literacy, and legitimately put environmental considerations into the curriculum.

One approach is to keep a file a clippings of items from newspapers, magazines, journals and other information sources that relate some aspect of the environment to some aspect of mathematics. There are a huge number of possibilities, as will be illustrated. Gradually get used to adapting such items for classroom use; eventually you will make frequent use of such items. They might lead to a simple homework problem or exam question, or illustrate some point in a lecture, or help generate classroom discussions. You do not have to wait until you have the time for a big project or a new course.

I believe you cannot depend on the textbooks for this. Though it is the fashion nowadays for textbooks to use real data and emphasize applications in many lower division college math courses, and rightfully so, texts doing this may try to cover a wide variety of applications, so cannot often include the environment. Even when they do, it may be that the examples may not do much to encourage interest in either the environmental topic, or for that matter, in the mathematical topic.

For example, if you look in the "index of applications" in one mainstream text we use you will find a reference to "Recycling," which turns out to be this problem:

Let U = set of all participants in a consumer behavior survey conducted by a national polling group.
A = set of consumers who avoid buying a product because it is not recyclable
B = consumers who use cloth rather than disposable diapers
C = consumers who boycotted a company's products because of their record on the environment
D = consumers who voluntarily recycled their garbage

The problem requests a verbal description of *A* intersection *C*, *A* union *D*, *B* complement intersection *D* etc. The author could at least have used set *C* for the Cloth users and *B* for the Boycotters to help keep the categories straight! And while it is nice to raise these recycling issues, who really cares about these unions and intersections? Though students do need drill, I do not see how this problem will generate interest in either set theory or recycling.

Another example from a competing text that has one reference to "smog control" in its "index of applications":

A new smog control device will reduce the output of sulfur oxides from automobile exhaust. It is estimated that the rate of savings to the community from the use of this device will be approximated by $S(x) = -x^2+4x+8$ where $S(x)$ is the savings (in millions of dollars) after x years of use of the device. The new device cuts down on the production of sulfur oxides but it causes an increase in the production of nitrous oxides. The rate of additional cost (in millions) to the community after x years is approximated by $C(x) = 3x^2/25$.

The question goes on to ask how many years one should use this device and how much can be saved. It is good to give students practice with such problems, and help make them aware of costs, benefits (especially that there might be dollar benefits from pollution removal!) and trade-offs, but it is evidently a pretty artificial problem. Who estimated such a formula? We know how sensitive that is to the interests of the estimators! For what interval of values of x might this be good? Not stated. Those who follow pollution issues know that cars are not a major source of sulfur dioxide. The prediction of $12 million in benefits after 2 years but a loss of $52 million after 10 years (within the lifetime of an automobile) sounds implausible.

Another problem from the second book, indexed under "pollution:"

Pollution from a factory is entering a lake. The rate of concentration of the pollutant at time t is given by $P(t) = 140t^{5/2}$ *where t is the number of years since the factory started introducing pollutants into the lake. Ecologists estimate that the lake can accept a total level of pollution of 4850 units before all the fish life in the lake ends. Can the factory operate for 4 yr without killing all the fish in the lake?*

Does this problem suggest it is OK to kill 90% of the fish in the lake? The pollutant is unnamed, and the author does not even bother identifying the units of the pollutant. I doubt this can help develop much interest in either the environment or in mathematics.

Contrast that example with this one from the Fall 1993 newsletter *Science for Democratic Action* which has a regular section called "Arithmetic for Activists."

You live one mile downwind of a uranium mill. Your trusty air monitoring equipment measured the amount of radioactivity in the air. You read 0.00037 becquerels per liter of air. Remember that 1 curie = 37 billion becquerels and that the prefix 'pico' means one trillionth. Laboratory analysis indicates this is all due to insoluble radium-228—are you above the standard?

It is noted that the existing standard of insoluble radium-228 is .001 picocuries per liter.

This time there is no escaping the need to pay attention to units. [Though we do not mine for uranium in New England, I do like this problem. Our region is relatively dependent on nuclear energy but almost nobody pays any attention to the details.] This problem is copied to my file, so it can be used in a "technical" math or quantitative literacy class.

I think if we are to get good real examples, it is clear we cannot depend on textbooks but should expect to gather them ourselves from a variety of sources.

Though even beginning liberal arts statistics courses try to cover as much statistical inference as possible, we are more likely to be training citizens in these courses than researchers. Therefore, on the first day of the course I mention the most basic interpretation of the word "statistics" as a set of meaningful facts and figures. To illustrate this, I show a slide of one of a "Harper's Index," a monthly compilation of interesting statistics in that sense. The students see that numbers can indeed be interesting, not only in the judgement of statisticians, but in the judgement of magazine editors who are in the business of selling magazines. Indeed the "Harper's Index" is successful enough to be a registered trademark. There is even a "Harper's Index Book" paperback! Examples from the February 1997 Harper's Index include:

Amount that "side agreements" in NAFTA require that the U.S. spend on environmental cleanup: $1,500,000,000
Amount the US had spent by the end of 1996: 0

Older indices include:
The number of Exxon Valdez spills it would take to equal the amount of oil spilled into the Mediterranean each year: 17;
Estimated percentage of the $6.7 billion spent on Superfund cleanups since 1980 that has gone to lawyers: 85;
Square yards of park per inhabitant: Paris 6, New York 18.

You get the idea—some amusement, but also some seriousness. If you flash a slide of an Index on a screen and ask students what is interesting about the items, they may well single out those with an environmental theme. The Indices also include numerous percentages, averages, probabilities, and ranks, but the idea is not so much to teach mathematical terminology as to encourage students to develop a lifelong belief that quantitative information is interesting and worth paying attention to.

One actually needs to clip the "Harper's Index" pages to have it available when needed. One of my colleagues who knows I use this sort of thing actually gives me a copy of the "Index" each month, and I occasionally get similar materials from other colleagues and students who know I like to collect such information. Many others use the idea of the "Harper's Index." For example I have a "Vital Statistics" page from the National Wildlife Federation which includes these items:

Estimated global pesticide sales in 1975: $5 billion, in 1990: $50 billion
Parts per million of DDT in human adipose tissue in the US in 1970: 8 in 1983: 2

See? Do not always assume bad news!

"Harper's Indices" have numerous references to very large numbers. This is one of the first topics developed by John Allen Paulos in his book *Innumeracy*, (indeed it is referenced in the second line of the book!) because of the difficulty even educated people have in dealing with numbers in the billions, trillions etc. Think of the problem mentioned before about the picocuries. Do you have colleagues who tend to refer vaguely to zillions? It seems even newspaper headline writers do not pay adequate attention. For example, I clipped a headline from the May 16, 1984 Providence Journal that says "Waste Cleanup Cost: up to $26 million." We wish it was $26 million! More than that was spent on just one superfund site in Rhode Island, the Piccillo Pig Farm. The article clearly says the cost was up to $26 billion, but apparently millions and billions were all the same to the headline writer.

What we can we do to humanize the $26 billion figure? As it was supposed to be spent over a twenty year period to clean up the sites, one could ask what it would cost on average per person, per year. One thing I like about that question is that you have to divide twice. Textbook problems illustrating the mean never seem to have such questions even though there are numerous real situations where it applies, and some students are puzzled about what to do. Another thing I like about the question is that the answer comes out so small, only about $5 per person per year. Indeed one student told me he thought it must be wrong, it was so cheap. Perhaps that is how we should argue before Congress when debating spending money on hazardous waste cleanups.

Humanizing large numbers by reducing them to a per person or per household basis as done above can be applied to a variety of situations. The process can also be reversed to see the cumulative impact of what sounds like insignificantly small numbers. For example, because of my interest in the impact of transportation on the environment, I get a lot of information on that topic from a variety of sources. Parking cashout is a strategy to reduce vehicle miles by having employers who offer free parking also offer the cash value of the parking as an alternative for employees who don't use it. A parking cashout leaflet from the Conservation Law Foundation (based on a study at the UCLA School of Public Policy and Research) suggested that parking cashout can reduce auto commuting by about 625 vehicle miles per month per employee. Assuming each mile of auto use produces about .4 ounces of carbon monoxide and .038 ounces of nitrogen oxide emissions, which sound insignificant, one can ask for a reasonable estimate of the effect of how a national parking cashout program might influence the total weight of the output of these pollutants. One would need an estimate of the total labor force, and what percentage gets free parking. A ballpark estimate for the total might be of order of magnitude of a billion pounds of carbon monoxide and about 100 million pounds of the nitrogen oxides, which does sound significant.

Another example of going from a small human scale number to a large number relates to solid waste. This is a topic that has gotten much attention here due to problems at the state's central landfill (literally one of the high points of Rhode Island. Look for it if you ever fly in to Providence) and several attempts to build solid waste incinerators, which alarmed people living near the proposed sites. I relate this to a problem in one of our current textbooks (in our math for elementary teachers course) asking for the surface area of a cereal box of dimensions 11" by 2.5" by 8". A check of my favorite cereal box shows that these dimensions are realistic. But instead of stopping at the answer to the textbook question (271 sq in), why not go on to consider the surface area of a cube that would enclose the same volume? It may surprise some students that the same volume can be enclosed by only about 219 sq inches of box, a savings of 52 sq in or about 19.2%. Ask for a reasonable estimate of the number of cereal boxes sold in a year (100 million households times 50 boxes a year per household was suggested) to get an estimate of the total reduction in packaging possible from redesigning cereal boxes. Ask the class why isn't cereal sold in the shape of a cube. Would they buy a box of cereal in the shape of a cube? What happens if the dimensions are modified to make it only somewhat more cubelike?

There are marketing considerations here; the cereal companies want to have a large face area on which to show their brand name and logo. I do think, and sometimes say, that the cereal producers do not have to worry much about the cost of disposing of the empty boxes. At any rate, it is helpful to have a file of solid waste clippings available. For example, one such article, perhaps relevant to the cereal box example, indicates paper and paperboard constitute 40% of our waste stream, a considerable percentage. It also says that the Northeastern Governors have asked industry for voluntary cooperation in reducing packaging though none of my students thought that industry would actually pay any attention to such a request.

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Indeed the September 1995 Harper's Index notes the chances that an American seventeen year old can express 9/100 as a percentage is 1 in 2.

The cereal box example makes a good multistep problem, starting just with the dimensions of the cereal box. Every math teacher knows students will do OK on one step problems—they learn the procedure—but do badly on multistep problems even if they really know how to do each step. There just isn't enough practice with such problems. We math teachers have to be on the lookout for them ourselves.

That example also opens up the possibility of a percentage of percentage question. What would be the impact of a 19% reduction in 50% of the 40% of our solid waste stream? In the ideal world all students would be able to deal with percentage problems, but in the world I live in that topic is apparently not well reinforced in the usual high school math curriculum of Algebra I, II, and Geometry. So many students need help, and practice, on percentage problems. Indeed the September 1995 Harper's Index notes the chances that an American seventeen year old can express 9/100 as a percentage is 1 in 2. So solid waste issues can lead to many percentage problems. An example I've used relates to the fact that Rhode Island, unlike our neighboring states, does not have a "bottle bill"—that is, mandated deposits on beverage containers. When that was being debated here a flyer used by the Bottle Bill Coalition included this item that I used for this percentage problem: "According to *Beverage Industry Magazine,* the US soft drink companies spend $4.5 billion annually for packaging their product and about $800 million for ingredients. What percentage of the total of these costs is for packaging?" Sadly, many students didn't handle this correctly, dealing badly with the percentage or with the large numbers involved. Also sadly, the item didn't help pass the bottle bill, which our neighboring states have found to reduce litter and increase the recycling rate.

I have in my solid waste file a full page ad from the American Plastics Council entitled "Plastics. An Important Part of your Healthy Diet." I haven't decided how to actually use it, if at all. What is significant is that it has no quantitative information whatsoever.

While on the subject of relating human scale activities to environmental issues, consider this example. Amtrak, our intercity rail passenger service, is facing severe financial constraints and has asked that one half cent of the gas tax be set aside for capital improvements for Amtrak. There is a letter to the editor from some motorist objecting to how their hard earned dollars would be going to a service they do not use. I suggest asking for a quick guess of how much this will actually cost a typical motorist. Then ask for a procedure to come up with a more reliable estimate. For example, if you drive 15,000 miles per year in a vehicle that gets 20 mpg, the total cost of the half cent tax would be about $3.75/year which a student said was "nothing." Indeed it does seem like quite a bargain to keep a rail passenger system alive that might someday provide an alternative for even the most train-phobic motorists, or at least help reduce traffic on the roads for those who must drive. But the point to make to students is: "do a calculation to see what it means to you."

By the way, I've found that even environmentalists are often unaware of just how much Amtrak survival is an environmental issue. I have an article indicating the pollution in grams of hydrocarbon emission per passenger mile is about .1 for the rail mode, .2 for buses, and 2.1 for a single occupancy auto. There are similar figures for carbon monoxide. There is also fuel efficiency and all the impacts that energy extraction and transport have on the environment. Amtrak says it can carry 550 passengers one mile on only 2 gallons of fuel while 110 five passenger cars would take 8 gallons to do this. This could turn into various questions for a class—what does this assume about the automobile mileage? If true, what is the macroscale impact?

I do not want anyone to think only information from environmental groups and articles that make some kind of pro-environmental point are to be used. The American Automobile Association puts out annually a summary of the costs for operating an automobile. One of these says the cost of owning and operating a new car (for 15,000 miles) is "now averaging 38.7 cents per mile... Average per-mile cost is determined by combining operating and fixed costs... motorists nationally paid an average of 9.16 cents per mile in operating cost (gasoline, oil, maintenance, tires). Fixed costs, which include insurance, depreciation, registration, taxes and financing, average $12.14/day." I use this in our first "quantitative business methods" course, asking students to read the article, develop the formula, and do some calculations. There is some need to be careful about units—it's amazing that sometimes students do not distinguish correctly between dollars and cents—in asking them to verify the formula or estimate the cost of driving 10,000 miles in a year. A larger environmental point can be made by looking at the percentage of the total cost of driving, that is the marginal or operating cost, which is only about 17%. I believe the relatively high fixed cost but low marginal cost is related to the difficulty of reducing vehicle trips, that is, it doesn't cost very much more to do a little more driving.

An example I use to illustrate functions and marginal costs is taken from information I've filed from the New England Power Company that generates electricity for our local utility. It has a graph of the cost (to the power company) of removing pollution from the stacks as a function of the percentage of pollution removed. Of course it rises quite steeply after a while, actually after about 78% removal. Some students may be disappointed about what that implies for simply requiring 100% removal. Perhaps it is just as well the Congress of the 1970s did not see such graphs when they were writing the clean water laws intending to eliminate all discharges.

Energy issues are a good source of mathematical ideas. First, numerous data lists have been published, with meganumbers sometimes making interesting points. An example from our local paper is that the cost of the nuclear plant in Seabrook, NH, is enough to pay for all municipal services in Fall River for 51 years!

New York's Con Edison utility had an energy quiz in the *New York Times*. A sample question follows. Do you know the answer?

Burning the oil required to light one ordinary 75 watt bulb for a year releases how many pounds of gases that might contribute to environmental problems? (a) 275 pounds (b) 5 pounds (c) 12 pounds (d) 1 pound.

Con Ed said the answer is (a). A less benign example from our gas here is in its rate structure. A handout given to customers describes this monthly commercial rate structure: "Customer Charge is $8.15. First 4000 ccf 63.57 cents per ccf. Over 4000 ccf: 55.76 cents per ccf." This gives us math teachers the opportunity to discuss not only a real piece-wise defined function (writing it algebraically poses more of a challenge for students than I had anticipated) but also marginal costs and the effect of a declining rate structure on the conservation ethic.

Another energy item from the New York Times relates to power line electromagnetic fields and cancer. The headline reads "Federal Panel Says Electric Fields Pose No Known Hazards," but the article itself says that "the statistically weak link between leukemia and proximity of large power lines may be due to unknown factors with no connection to electromagnetic fields. Possible outside factors which need to be looked into more closely include the age of homes and their construction features, pollution, local air quality and heavy traffic near power lines..." This can be a good springboard for a discussion of confounding in statistics. I can also say that, despite the headline, the article did not encourage my students to locate near a power line.

Being on the lookout for examples of confounding in an environmental context can be rewarding. For example, the students see the point instantly in a *New York Times Week in Review* headline "Reading at 55 Miles Per Hour" which reports that accidents were 41% higher when billboards were around. It would be nice to use this to justify removing the billboards and so improving the scenery, but it can be simply that advertisers prefer them where there is heavy traffic.

Population growth models are a staple of environmental mathematics, and there are plenty of graphs from environmental groups showing exponential type growth. A more unusual graph is from the 11/17/96 *New York Times* headed "The Population Explosion Slows Down." The "today" point on the graph is just where the rate of increase starts dropping. It came just at the right time for my Calculus I class studying the second derivative. When I put up a slide of this graph, they immediately saw it as a point of inflection. However, anyone using this beware: the slowdown in growth is only a projection!

Do not think always being on the lookout for examples that can be used in classes will make it too hard to just relax and read the paper. I believe it is worth some effort to be able to use a wide variety of topics. Here are some miscellaneous examples to show this:

Reading that Sarawak (in Malaysia) had 21,000 square miles of rain forest but it was being destroyed at a rate of 1000 square miles per year became both a linear equation problem and a comment about the destruction of the tropical rain forest.

Transportation provides items such as an actual probability distribution for the number of motor vehicles per household. You do not have to make up a hypothetical one and you, like my students, may be surprised that the city of Providence reports 23% of their households have no cars at all, a group usually forgotten about by local transportation planners with cars. The entire distribution for 0, 1, 2, 3, 4, 5 vehicles is .23, .42, .27, .06, .016, .004 respectively. Transportation also provides such formulas as this formula which I use to illustrate real world functions:

$$C = 0.88 + 27.04/S + 23.874/U$$

where C = annual cost per vehicle mile for a bus system, S = average operating speed, U = peak vehicle utilization. Note what happens as S -> 0 as gridlock develops!

Roundoff can be important! An environmental group commenting on a proposed ozone air quality standard of 80 parts per billion warns not to allow roundoff (to 80ppb) from actual pollution levels up to 85 ppb to meet the standard. In other words, they want the 0 in 80 to be a significant digit so that a reading of 80.5 ppb would be a violation to be addressed. They say "rounding up means people have to breathe more pollution in the air."

This poll result in the *New York Times* can illustrate how newspapers may report the margin of error in surveys: 20% favor reducing spending on the environment, 74% say that is unacceptable. The *Times* explains that in 19 cases out of 20, samples of the size used would result in a margin of error of no more than 3% either way. We can get an interpretation of 95% confidence intervals while indicating something about public support for the environment.

Teaching at a state college where most students are Rhode Islanders leads to looking for a local angle. Perhaps attention to the nearby is a good idea everywhere. Here I note it is easy to get data, graphs, and information on such local environmental issues as the depletion of fish off our coast, pollution of Narragansett Bay, transport of air pollution, etc.

Well, what do students think of all this? I would like to live in a world where my ideas get universally favorable responses (some colleagues seem to live in that kind of world), but I think a more accurate summation is obtained by this quote from our student evaluation forms: "Instructor tried hard to bring interesting side issues into mathematics, sometimes successfully."

By now, my files of such articles are quite large. I would be glad to share any of them with colleagues who write to me at Rhode Island College. I do believe that such files can be used to encourage students to maintain a lifelong interest in paying careful attention to quantitative information, especially with regard to the environment.